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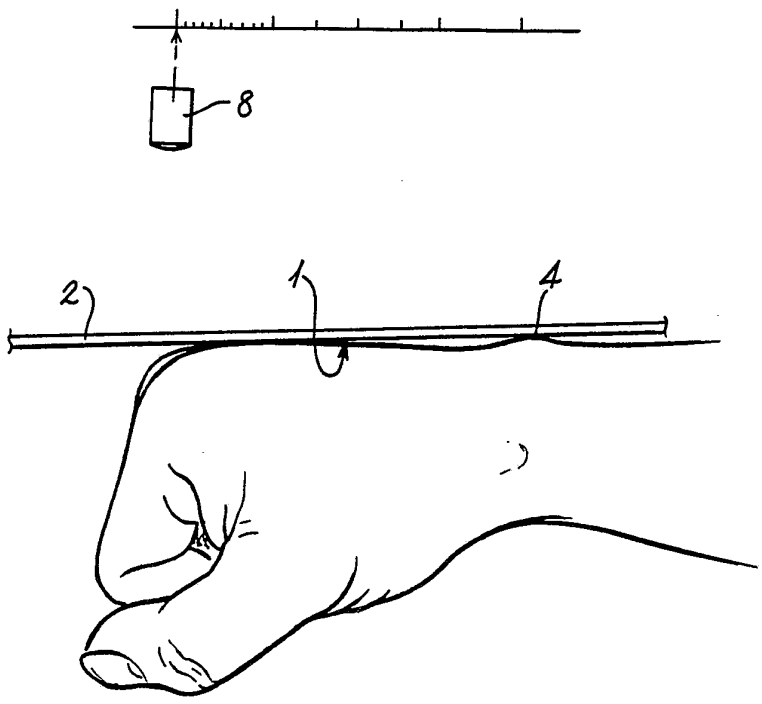

(57) Abstract

Apparatus for the identification of individuals comprises a plurality of measuring means for measuring a corresponding plurality of biometric parameters of an individual, a comparator or comparators for comparing the outputs from the measuring means with sets of stored values and combining means for combining the outputs of the comparator means to produce either an acceptance or a rejection signal dependent on the combined results of comparisons made by the comparator.

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BIOMETRICS

This invention relates to biometrics and, in particular, to measurements used for the identification of individuals.

With any measurement that is to be used for identification purposes it is essential to estimate the accuracy and the repeatability of the measurement. In the case of measurements on human parts it is necessary to allow tolerances because of variations of temperature, humidity, diet, etc., over the time interval between the instant at which the measurement was made and that at which the reference measurement was made. It is pointless measuring something to an accuracy of microns if variations in the measurement amount to millimetres. Secondly an appreciation of the laws of statistics is essential. Almost any measurements of any human parts are most likely to be statistically normally distributed. The consequence of this is that many more people produce measurements which are closer to the average than those which are unusual, making it easier for an intruder who has average measurements to masquerade successfully. This makes it particularly difficult to devise any biometric identification scheme which will cope with average human beings. Another law of statistics indicates that additional measurements are most probably related to a first measurement so that they have less information value than the first measurement.

There already exist devices which measure the lengths of the fingers of one hand, either by mechanically feeling or by optically scanning. The measurements are then compared with corresponding values stored either in a master file or in a chip card and a decision is made either to accept or reject the candidate or culprit depending on the closeness of the measurements to the registered values.

The principle behind this method is that, after growing through childhood, the dimensions of bones remain constant for many years. If we could really make contact with the bones of

the hand we could measure their dimensions with an accuracy of a few micrometres, and be able to consistently repeat such measurements over intervals of years. Such measurements could form a sound basis for identity verification. Unfortunately the bones are covered with soft tissue which is elastic and not constant in dimensions so that any measurement made through the skin can be subject to a substantial margin of error and lack of repeatability. Accurate measurements could probably be made using X-rays, but this is unlikely to be acceptable as a general purpose identification scheme.

Existing devices take measurements of the hand while it is spread on a flat surface, so that measurements suffer from the inconsistencies of the web between the fingers and the variations in length of the finger nails. These inconsistencies probably amount to about plus or minus one millimetre, so it is pointless to try to make measurements with units much smaller than a millimetre.

The average length of the middle finger of adults is about 85mm, with a probable deviation from 75 to 95mm. If measurements are quantised into, for instance, one millimetre units then one measurement would divide the total population into 20 very unequal categories, with a large proportion of the population having a finger length close to the average. Of course the lengths of the other fingers can be measured but here the second law of statistics applies, that is that alternative measurements are likely to be correlated with the first measurement. In this case the relative lengths of the fingers are likely to be close to standard proportions, so that it is only the departures from these standard proportions which are of value. If these departures are small compared with the tolerances, then the measurements are of little significant value.

In our British patent No.2156127B there is described a means of identifying individuals by scanning the subcutaneous vein structure and comparing it with a set of previously input stored

values.

Whilst this provides a satisfactory method for identification, in order to avoid ambiguity and either false acceptances or false rejections, it is necessary either to make repeated scans or to make measurements at a very high resolution. On occasion, this is not feasible. We have therefore devised more rapid techniques based on making a plurality of measurements and combining the results. This technique gives a high acceptance/rejection accuracy with a much higher speed of measurement.

Preferably, the hand is used as the medium for biometric measurements because it is readily inserted into a measuring device and it possesses a number of parameters which are easily measured but are substantially independent of one another.

According to the present invention there is provided apparatus for the identification of individuals comprising a plurality of measuring means for measuring a corresponding plurality of biometric parameters of an individual, comparator means for comparing the outputs from said measuring means with sets of stored values and combining means for combining the outputs of said comparator means to produce either an acceptance or a rejection signal dependent on the combined results of comparisons made by said comparator means.

The apparatus preferably includes measuring means for measuring at least two substantially independent biometric parameters.

The apparatus may also includes measuring means for measuring at least two partially correlated biometric parameters.

The invention will now be described with reference to the accompanying drawings, in which:

Figure 1 shows a side elevation of a clenched fist with protuberances due to the underlying bone structure;

Figure 2 shows a corresponding plan view of the fist;

Figure 3 shows the bone structure of the fist of Figure 2;

Figures 4 a to c show in plan and section a finger nail with

extrusion ridges thereon;

Figure 5 shows the underside of a pair of hands with the major creases which are visible on the surface of the skin;

Figure 6 shows a hand playing a keyboard;

Figure 7 is a schematic drawing of an apparatus used for biometric measurements for purposes of identification; and

Figure 8 is a graph showing the effect of tolerance settings on customer rejection rates;

Figure 9 is a schematic drawing of apparatus suitable for credit card verification.

We have found that an analysis of the topography of the knuckles is a useful basis for person identification. Insofar as knuckles appear to be a complicated three dimensional pattern of a skin surface, the problem of recognition is similar to the problem of recognising human faces, but without the problem of variable hairy excrescences or spectacles.

Referring now to Figures 1 to 3 of the drawings, more accurate and more consistent measurements of bone lengths can be achieved by taking measurements of the clenched fist, locating the back of the hand 1 against a reference surface 2 and measuring the distances L1-L4 of the end of the metacarpals 3-6 from the styloid process 7 of the ulna with an optical gauge 8. In this way the thickness of the tissue is reduced to a minimum and measurements with a consistency down to a tenth of a millimetre are possible. Such an improvement in accuracy much improves the ability to discriminate against intruders.

It is always important to estimate the probability that an intruder having average measurements will be successful. Machines designed for identity verification are fitted with an adjustment to control the threshold between false acceptance and false rejection. If this is adjusted so that the number of false rejections is small, there is a temptation to believe that the machine is working well, whereas the machine is more likely

to accept an intruder.

There is a need to find measurements of a number of different kinds, so that they are related to each other as little as possible. If measurements are normally distributed, there is also a need to assign a low weighting on those measurements which are close to the average.

With vein patterns, first the problems of reliably locating the blood vessels must be overcome. Optical, infra-red and far infra-red wavelengths are in use for diagnostic purposes in the medical field. Each of these technologies has its advantages and limitations. Far infra-red waves penetrate deeper but give correspondingly less resolution. At optical wavelengths, colour filters can be used to provide more detailed information, but only of the surface. To achieve good thermal images it is standard practice to allow time for the temperature distribution of the patient to normalise before the thermal scan. This implies that there are problems with thermal time constants, particularly when the patient has been subjected to extremes of temperature. It is known that the body automatically modifies the flow of blood to the arms and legs in order to maintain the temperature of the central part of the body within close limits, with the result that the hands and feet can become very cold in cold weather. It is also known that scratches and inflammation on the back of the hand result in local hot areas, thus confusing the thermal image.

When the blood vessel pattern has been captured, several techniques are available to analyse the pattern into features such as junctions, parallel lines, s-bends etc. One powerful method for this is two-dimensional auto-correlation. The pattern can then be described in terms of the distances between, and the orientation of, such features. This description is then compared with the stored description and a decision made on the basis of a closeness of fit.

The relative position of the main veins is likely to conform to a normal distribution because they are constrained by the

bone structure of the knuckles and the wrist. However the positions of the minor veins and junctions are unconstrained.

Other parameters are of value for identification. One of these is the extrusion pattern of the finger nails (Figures 4a-c). This comprises a series of furrows 40 and ridges 41 which are scanned with a laser diode radiation source 42 and an optical detector 43. The signature of this parameter changes slowly with time as the individual ages or suffers accidents such as a blow to the growth point of the nail. It is therefore desirable to use measured values to update the stored reference, which thus becomes a moving average.

The palm (Figure 5) also has features which may be utilised. Specifically, the pattern of creases 50-55 on the palm is particularly useful because it is not correlated with size and because the pattern of the left hand is not necessarily identical with that of the right hand.

The creases 56-58 corresponding to the finger joints are gross features which are readily susceptible to optical measurement. Their relative positions from finger to finger provide a quantisable indication of identity, whilst their absolute spacings are correlated with the lengths of the metacarpals. This latter therefore provides for a check that the same hand is being measured when the measuring position has been changed.

Musicians who play instruments with a keyboard develop remarkable skills with their fingers. They are capable of learning phrases which their fingers can play very fast, quite accurately, and with very consistent timing. Typists develop similar skills. The proportion of the population who have finger skills is increasing at a considerable rate as computers become accessible to more people. Finger dexterity is therefore a further parameter which may be used for purposes of identification. For this purpose, a MIDI (musical instrument digital interface) keyboard 60 (Figure 6) would be appropriate as this is capable of encoding duration and velocity

characteristics of a sequence of key presses. Each candidate would choose and learn to play a phrase of between ten and twenty 'notes', concentrating on accuracy and constancy of timing. This phrase is used as a 'silent keyboard signature' to provide access to services. The probability of an intruder being able to produce the same 'signature' is very small. Because of this, it is probable that, for a restricted population such as the users of a computer installation, such a test could be used not only to confirm identity but also to declare identity. It can be implemented cheaply on a personal computer with the requisite MIDI interface, and requires a program which not only checks that keys are pressed in the correct sequence but also at the correct time intervals, within close tolerances.

Referring now to Figure 6, in use a biometric parameter is measured by an input device 71. After analysis in a signal analyser 72, the output from a signal processor 73 is stored in a look-up store 74. In subsequent live use, the values from the signal analyser 72 and the look-up store 74 are fed to a comparator 75 which controls a gating device 76 which control subsequent processing of the application.

The tolerance setting of the gating device is adjusted to give the desired acceptance rate (Figure 8).

In a practical application, an input device 91 scans a number of biometric parameters and passes the outputs to a signal processor 92 and subsequently to comparator circuits 93. Reference parameters are stored on an identity card 94 which is fed into a card reader 95. Data extracted by a management system 96 is fed via a signal processor 97 to the comparators 93. The comparators produce normalised output signals dependent on the difference between the input signals and the reference signals. These output signals are then fed to an adder 98 which produces a control signal for the pass/reject decision.

Conveniently the stored reference may be continuously updated by the most recent measurements so that it constitutes a

moving average. This will take account of long term changes in the biometric parameters used as a basis of the test.

PCT CLAIMS

1. Apparatus for the identification of individuals characteried in that it comprises a plurality of measuring means for measuring a corresponding plurality of biometric parameters of an individual, comparator means for comparing the outputs from said measuring means with sets of stored values and combining means for combining the outputs of said comparator means to produce either an acceptance or a rejection signal dependent on the combined results of comparisons made by said comparator means.

2. Apparatus for the identification of individuals as claimed in claim 1 characterised in that it includes measuring means for measuring at least two said biometric parameters.

3. Apparatus for the identification of individuals as claimed in claim 2 characterised in that it includes means for measuring the topography of the knuckles.

4. Apparatus for the identification of individuals as claimed in claim 3 characterised in that it includes means for taking measurements of the clenched fist.

5. Apparatus for the identification of individuals as claimed in claim 4 characterised in that it includes means for locating the back of the hand against a reference surface and means for measuring the distances of the end of the metacarpals from the styloid process of the ulna.

6. Apparatus for the identification of individuals as claimed in any one of the preceding claims characterised in that it incorporates means for measuring the positions of minor veins and junctions.

7. Apparatus for the identification of individuals as claimed in any one of the preceding claims characterised in that it incorporates means for measuring the extrusion pattern of a finger nail.

8. Apparatus for the identification of individuals as claimed in any one of the preceding claims characterised in that it incorporates means for measuring the pattern of creases on the

palm.

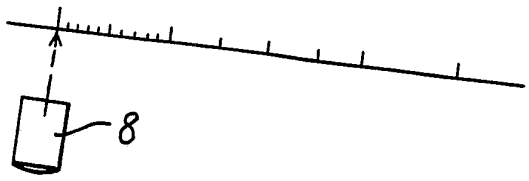
9. Apparatus for the identification of individuals as claimed in claim 8 characterised in that it incorporates means for comparing the pattern of creases on the left palm with that on the right palm.

10. Apparatus for the identification of individuals as claimed in claim 8 characterised in that it incorporates means for locating the creases corresponding to the finger joints.

11. Apparatus for the identification of individuals as claimed in claim 10 characterised in that it incorporates means for measuring the relative positions from finger to finger of the creases corresponding to the finger joints.

12. Apparatus for the identification of individuals as claimed in claim 10 characterised in that it incorporates means for measuring the absolute spacings of the creases corresponding to the finger joints.

13. Apparatus for the identification of individuals as claimed in any one of the preceding claims characterised in that it incorporates keyboard means responsive to the incidence and duration of imposed key strokes.



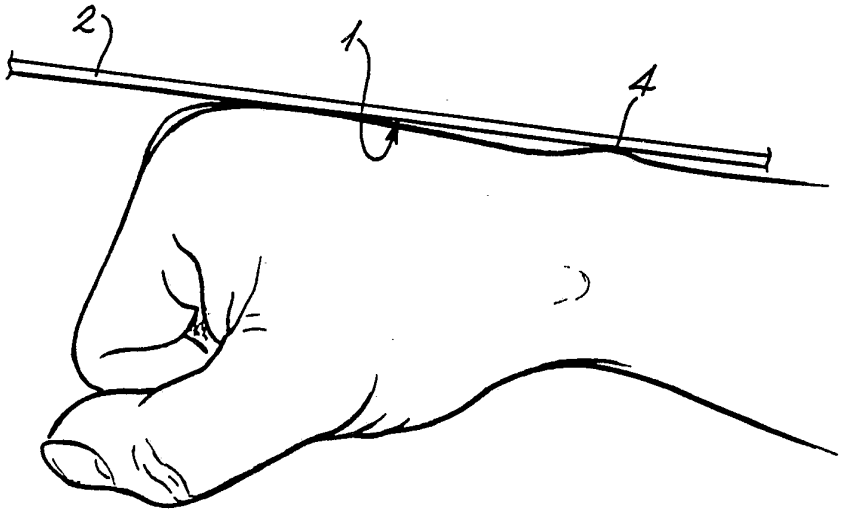


Fig. 1

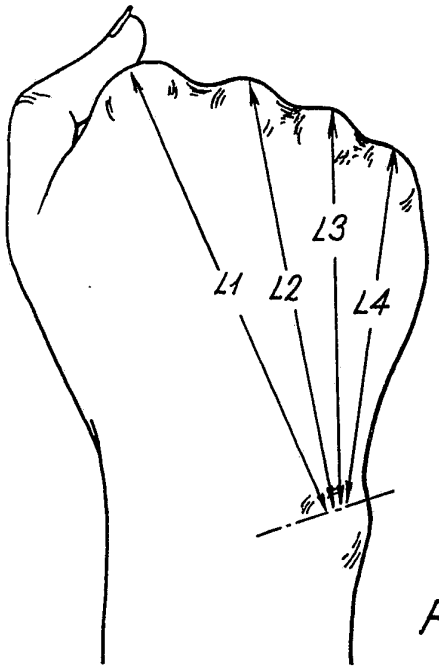


Fig. 2

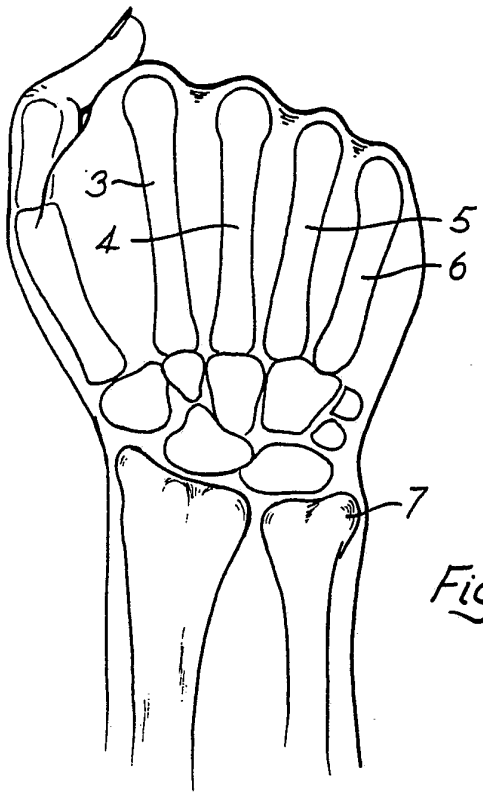


Fig. 3

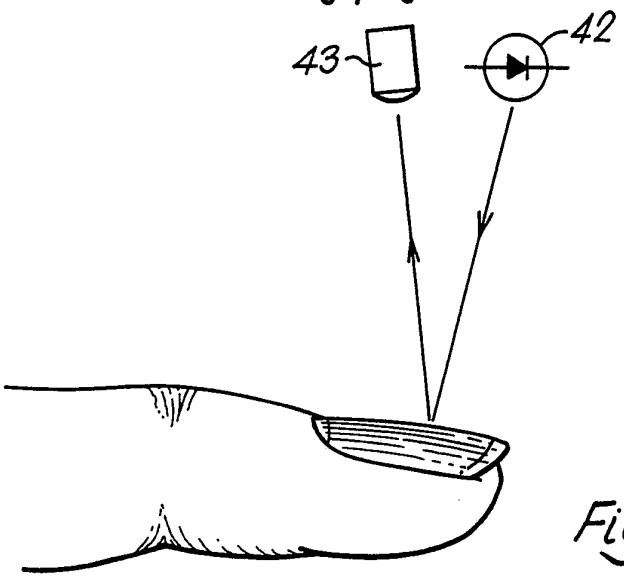


Fig. 4a

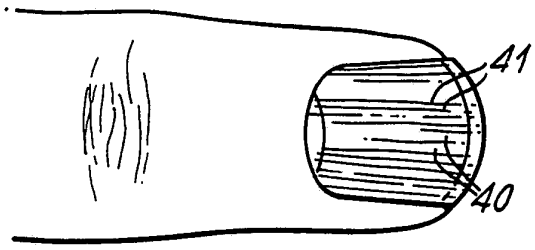


Fig. 4b

Fig. 4c

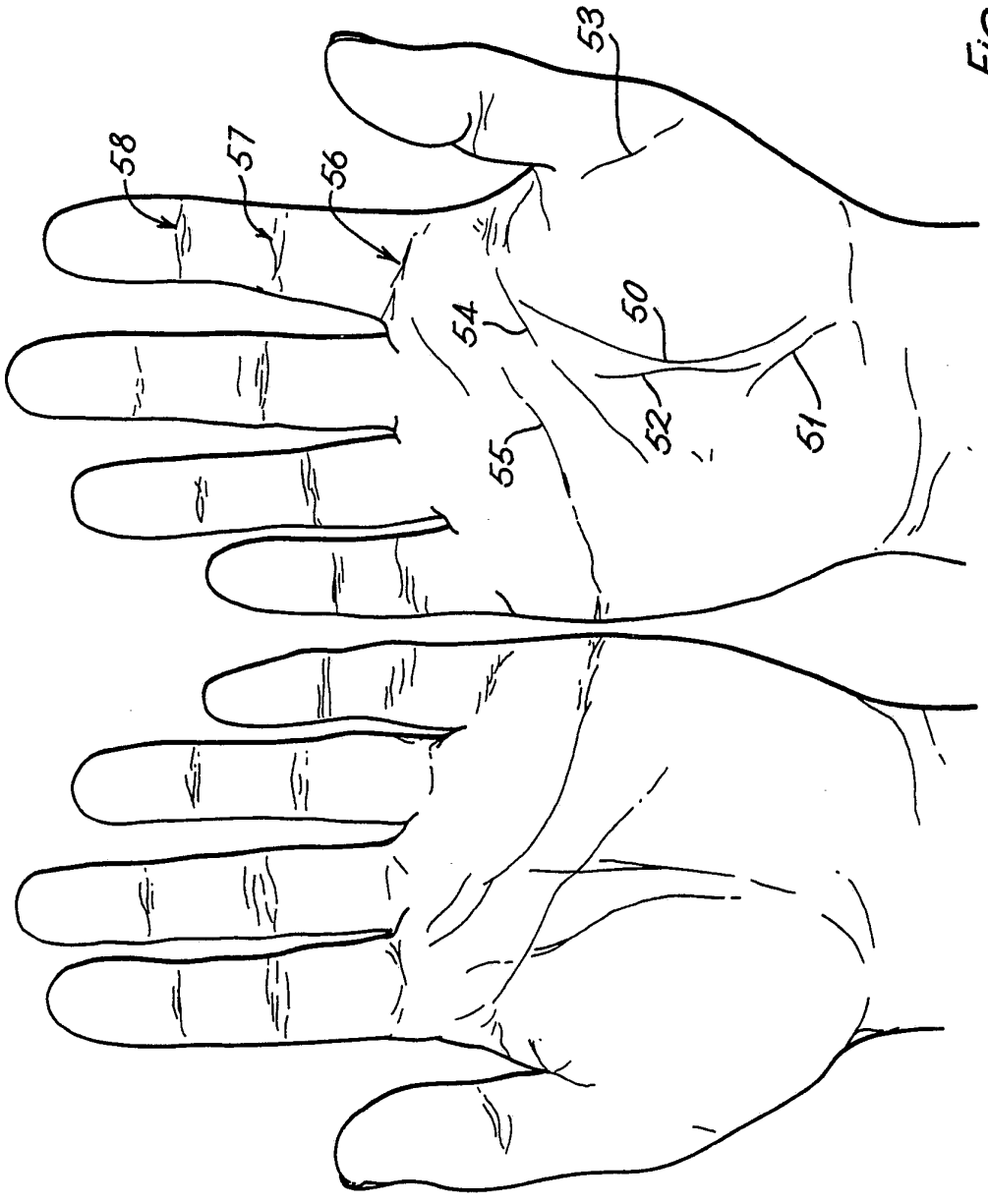


Fig. 5

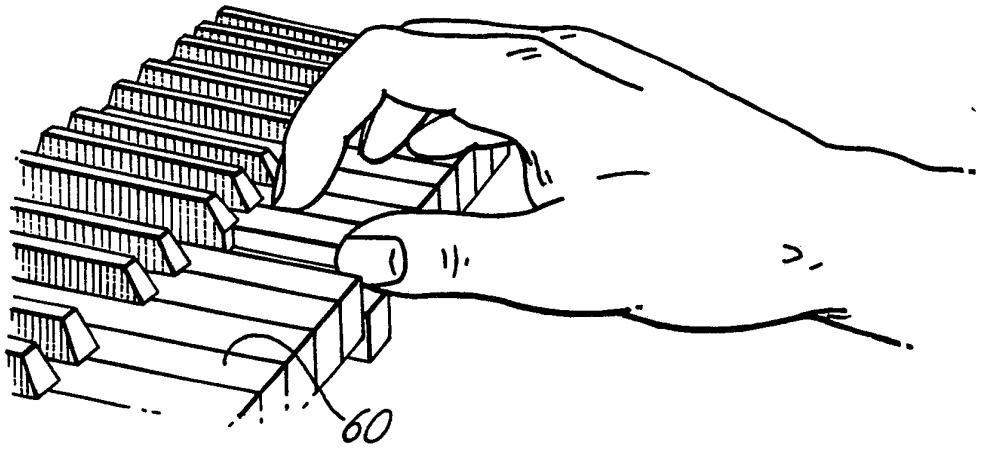


Fig. 6

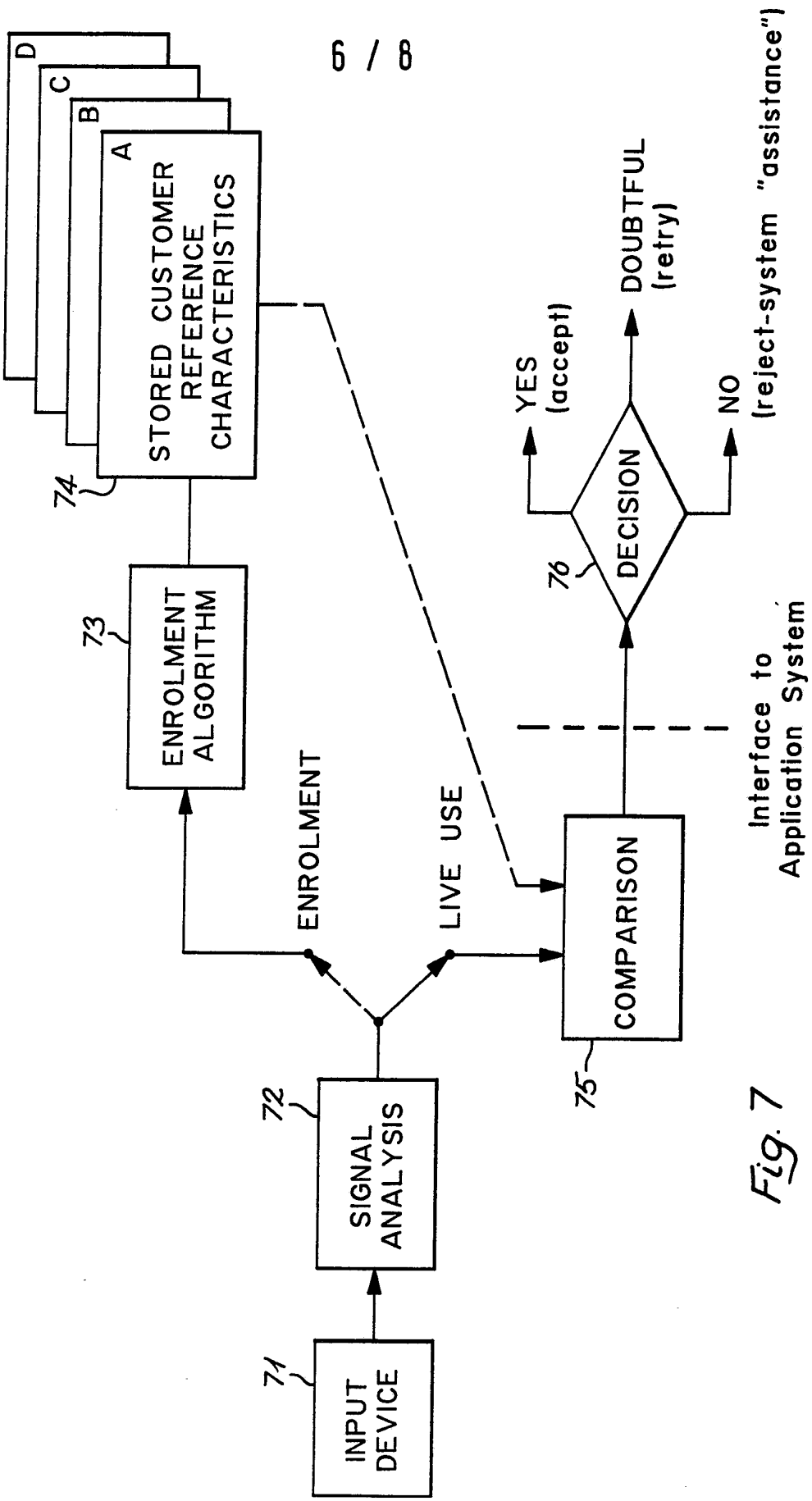

INPUT DEVICE
71
SIGNAL ANALYSIS
72
ENROLMENT ALGORITHM
73
STORED CUSTOMER REFERENCE CHARACTERISTICS
74
A
B
C
D
ENROLMENT
LIVE USE
COMPARISON
75
DECISION
76
YES (accept)
DOUBTFUL (retry)
NO (reject-system "assistance")
Interface to Application System

Fig. 7

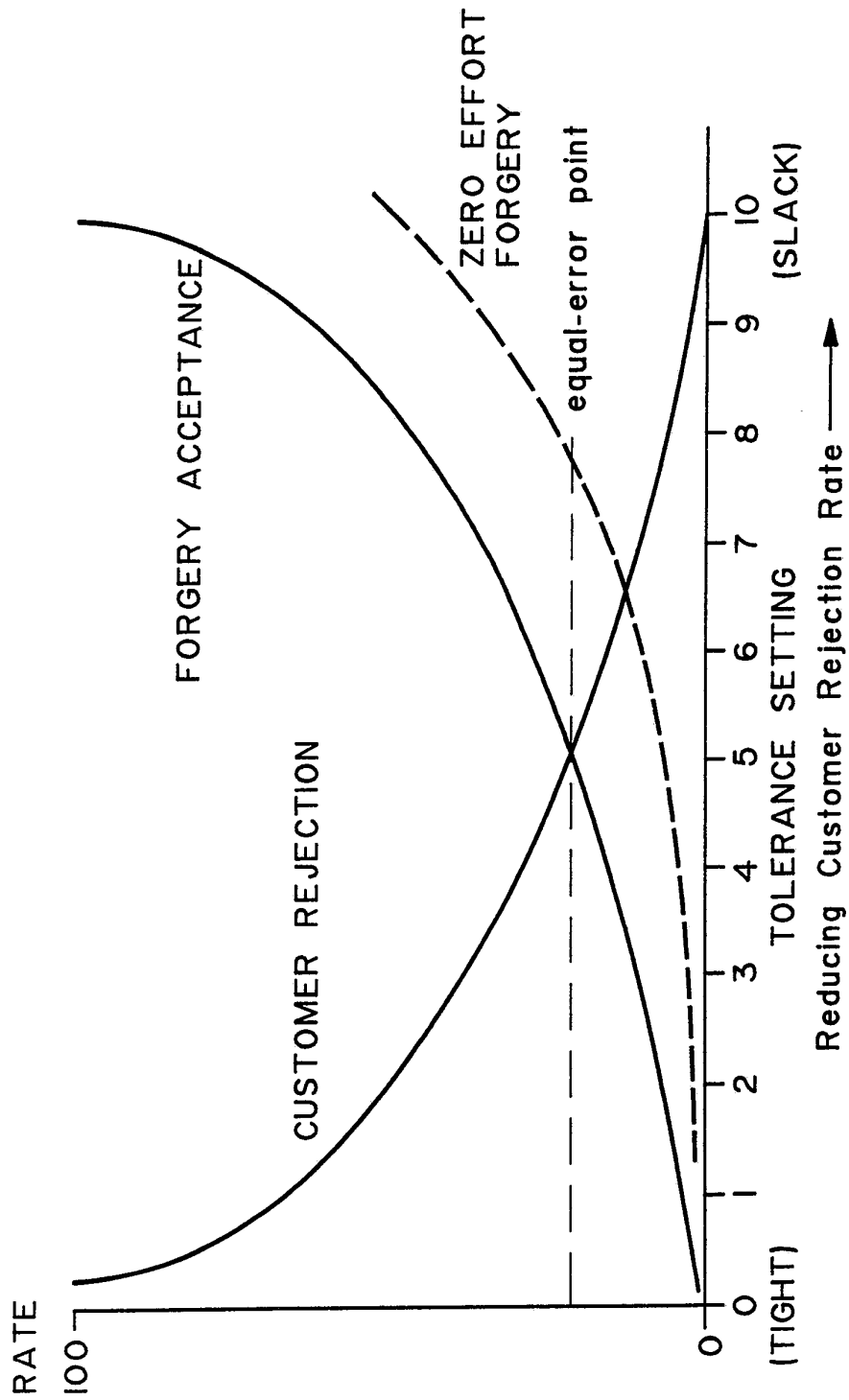

RATE
100
FORGERY ACCEPTANCE
CUSTOMER REJECTION
ZERO EFFORT FORGERY
equal-error point
0
1
2
3
4
5
6
7
8
9
10
(TIGHT)
(SLACK)
TOLERANCE SETTING
Reducing Customer Rejection Rate

Fig. 8

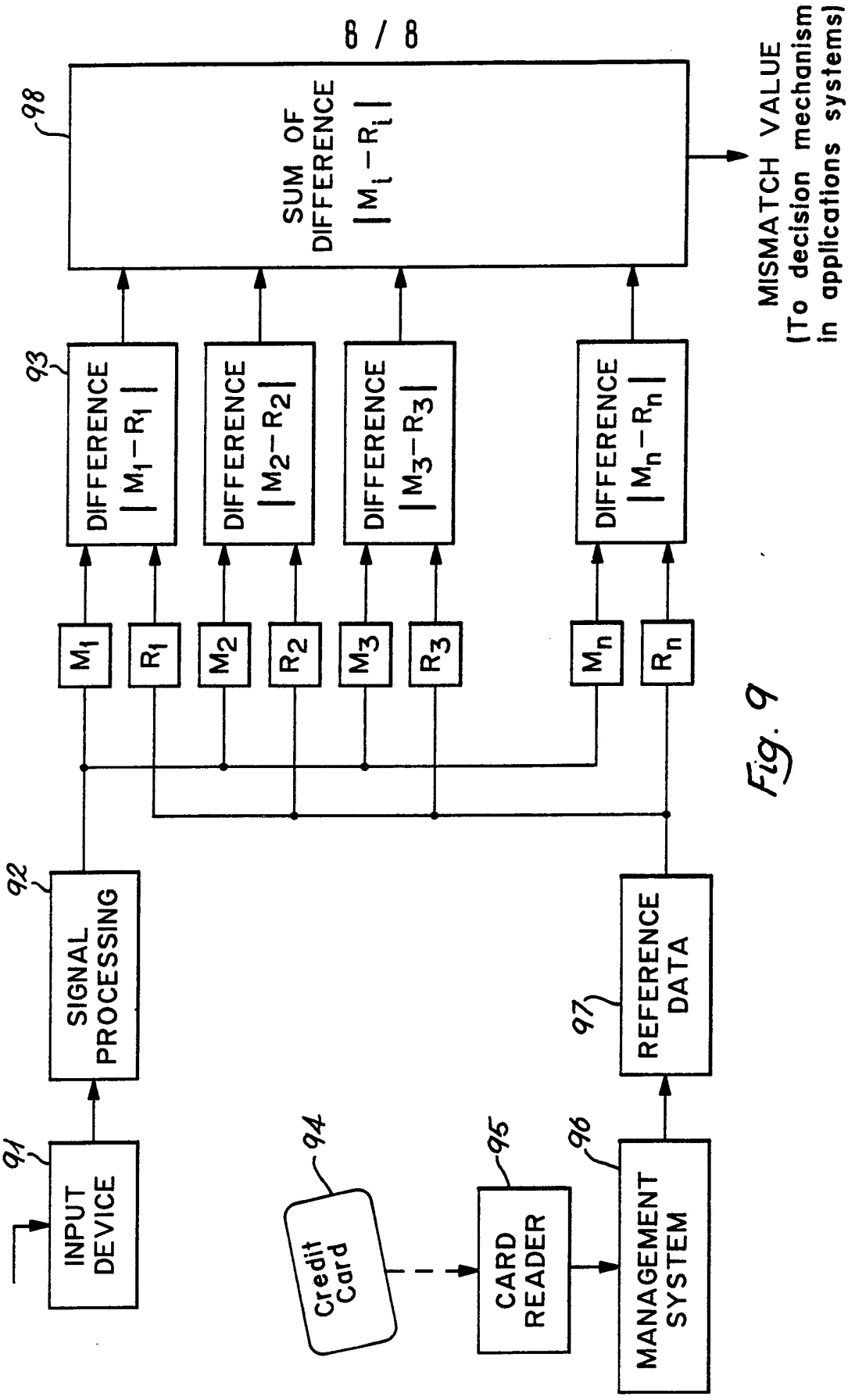

98
SUM OF DIFFERENCE $|M_i - R_i|$
MISMATCH VALUE
(To decision mechanism in applications systems)
93
DIFFERENCE $|M_1 - R_1|$
DIFFERENCE $|M_2 - R_2|$
DIFFERENCE $|M_3 - R_3|$
DIFFERENCE $|M_n - R_n|$
M_1
R_1
M_2
R_2
M_3
R_3
M_n
R_n
92
SIGNAL PROCESSING
97
REFERENCE DATA
91
INPUT DEVICE
94
Credit Card
95
CARD READER
96
MANAGEMENT SYSTEM

Fig. 9

INTERNATIONAL SEARCH REPORT

International Application No PCT/GB 90/00066

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all)[6]

According to International Patent Classification (IPC) or to both National Classification and IPC

Int.Cl. 5 G07C9/00 ; A61B5/117

II. FIELDS SEARCHED

Minimum Documentation Searched[7]

Classification System	Classification Symbols
Int.Cl. 5	G07C ; A61B

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched[8]

III. DOCUMENTS CONSIDERED TO BE RELEVANT[9]

Category [10]	Citation of Document, [11] with indication, where appropriate, of the relevant passages [12]	Relevant to Claim No.[13]
X	PROCEEDINGS OF 1981 CARNAHAN CONFERENCE ON CRIME COUNTERMEASURES; 13 - 15 MAY 1981; LEXINGTON, USA; PAGES 77 -82; WOODARD e.a.: "Automated entry control: RADC technology development results and future plans" see page 79, column 2, line 42, - page 81, column 2, line 70; figures	1, 2
Y		3, 4, 8, 10, 13

X	PROCEEDINGS OF 1976 CARNAHAN CONFERENCE ON CRIME COUNTERMEASURES; MAY 1976; LEXINGTON, USA; pages 23 - 30; HABERMAN e.a.: "Automatic identification of personnel through speaker and signature verification - system descryption and testing" * abstract; page 30, lines 6 - 62; figures *	1, 2

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"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
08 MAY 1990	23. 05. 90
International Searching Authority	**Signature of Authorized Officer**
EUROPEAN PATENT OFFICE	MEYL D.

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)

Category °	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No.
Y	IBM TECHNICAL DISCLOSURE BULLETIN. vol. 21, no. 6, November 1978, NEW YORK US pages 2523 - 2525; NASSIMBENE: "personal verification - knuckle contour detection" see page 2523, line 1 - page 2525, line 59; figures	3, 4
A	---	5
Y	CH,A,661428 (MENOUD) 31 July 1987 see page 2, column 2, lines 16 - 33; claims 1, 2, 7, 8, 10; figures	8, 10
A	---	9, 11
Y	IBM TECHNICAL DISCLOSURE BULLETIN. vol. 17, no. 11, April 1975, NEW YORK US page 3346 SPILLANE: "keyboard apparatus for personal identification" see page 3346	13
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A	WO,A,8804153 (KODAK) 16 June 1988 see page 2, line 4 - page 3, line 7; figures	
A	---	
A	GB,A,2171828 (MITSUBISHI) 03 September 1986	

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ANNEX TO THE INTERNATIONAL SEARCH REPORT ON INTERNATIONAL PATENT APPLICATION NO. GB 9000066

SA 33902

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report. The members are as contained in the European Patent Office EDP file on 09/05/90
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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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